Drainage characteristics of selected soils of the Weatherley catchment, Eastern Cape Province

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Abstract

The presence of standing free water in the soil profile causes variation in the redox conditions which are reflected in the soil morphology. The aim was to analyse the soil water regimes of soils of selected soil forms and correlate them with the redox morphology.

Tensiometer data and daily water balance modelling were used to estimate daily water contents from weekly NWM measurements made over a six year period in the Weatherley catchment.

Although the soil water regimes of all 28 soils differed, three similar water regimes occurred in three soils of the Longlands form. The soils occur on quite different landscape positions. The year cycles of the water regimes have distinct wet (three months), draining (two months), drying (five months) and wetting (two months) phases. Typical soils of the Katspruit and Tukulu forms have two (wetting and draining) and three (wetting, wet and drying) phases.

Keywords: *gley soils, hydropedology, plinthic soils, soil classification, soil water regime*

1 Introduction

The interaction of soil and water in the landscape has left its signature on the soil profile. These and other soil properties inherited form the parent material, influence the movement of water in the landscape and resulted in the coining of the word hydropedology. Hydropedology is a booming discipline world wide. It is only about 15 years old and therefore experiencing teething problems. Because the soils of the world vary, the concepts and norms developed in other countries are not transferable to South Africa. The first major project aimed at quantifying soil moisture regimes has been undertaken in the Weatherley research catchment near Maclear in the Eastern Cape Province.

Several norms for the diagnostic soil horizons and soil forms of South Africa were developed in this research (Van Huyssteen, C.W., Hensley, M., Le Roux, P.A.L., Zere, T.B. & Du Preez, C.C. 2005). Several concepts formed and vague theories about the behaviour of soils were improved. It is uncertain to what extend the South African soil classification system can be applied as vehicle for transferring this knowledge from one catchment to another. The soil types needs to be researched, characteristics confirmed and norms developed to contribute to the development of pedotransfer functions (PTF's). PTF's should meet the needs of disciplines interested in the impact of land use on land qualities.

Although the pedologists of South Africa have a good grip on the identification and classification of the 73 soil forms, the characterisation of specific features has received relative little attention. How the soils of different forms behave and the degree of similarity is quite uncertain. To understand hydropedology the behaviour of soils with redox morphology draws special attention. Soils with restricted drainage have one or more elements of redox morphology (Soil Survey Division Staff, 1999). South African soils with redox morphology are described as having a "fluctuating water table", "periodic saturation" and "saturated for extended periods of time" (Soil Classification Working Group, 1991). An important concept in this regard is that redox morphology develop in a soil at water contents between the natural drained upper limit and the condition at which all pores are water filled – termed saturation. Because of this Van Huyssteen et al. (2005) formulated a parameter defined as "the average annual degree of saturation above 0.7 of porosity" abbreviated as $AD_{s>0.7}$. Based on experience it was assumed that in most soils the drained upper limit would be around 60 % i.e. 0.6s. This was an important first step towards quantifying this element of the water regime of specific diagnostic horizons and soil forms. It is considered that an improved understanding of the water regime of soils and its drainage characteristics hampers the challenge to develop PTF's.

An improved understanding of the water regime of different soils may also aid in the understanding of the reaction of soils to rainfall events. Analysis showed that the duplex soils of Weatherley behave differently to low and high intensity rainfall events (Lorenz & Hickson, 2001). During a low intensity rain period the water drain through the topsoil and into the clayey subsoil horizons but after the high intensity rainstorm the water only infiltrated the topsoil and drained lateral leaving the clay layer unchanged.

Soil morphology, especially soil matrix colour and mottles is good indicators of the soil water regime. Many of which is differentiating criteria for the classification of the South African soils (Le Roux, P.A.L., F. Ellis, F.R. Merryweather, J.L. Schoeman, K. Snyman, P.W. van Deventer and E. Verster. 1999).

Interpretation of soil redox morphology implies that the soils in a catchment may impact on the hydrograph. If this hypothesis is true, then this impact should be visible in the hydrograph catchments with different soil patterns like Weatherley and Cathedral Peak (VI) (Van Huyssteen et al., 2005). The typical autumn drainage curve hydrographs of the two catchments are clearly very different (Figure 1). When the areas of the catchments are taken into account the outflows are 2.7 mm and 76.9 mm for Weatherley and Cathedral Peak (VI) respectively. Not only is more water delivered by the Cathedral Peak catchment during interflow, it also delivers it at a higher rate and over a longer period. Although the yearly mean rainfall is about the same the base flow at Weatherley catchment is two weeks compared to several months at Cathedral Peak.

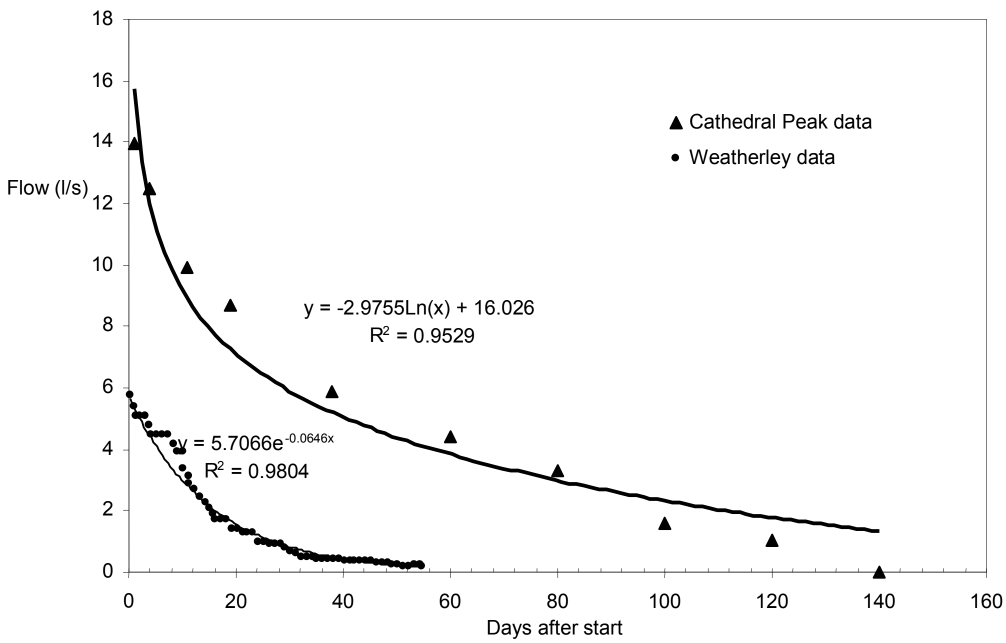

Figure 1 Typical hydrographs of interflow for the Weatherley and Cathedral Peak (VI) catchments during a rain-free period at the end of the rain season, approximately up to the stage when base flow starts.

An improved understanding of the water regimes of the South African soil forms may aid in quantifying the impact of soil and land use on the hydrograph and make "**Managing Water for People and the Environment**" a little easier.

2 Material and methods

The Weatherley catchment (31° 06' S; 28° 20' E) is situated approximately 4 km south of Maclear on the road to Ugie. The catchment is roughly 150 ha in extent and is approximately 1 340 m above sea level.

The geology of the study area consists mainly of sandstone, shale and mudstone of the Molteno Formation as well as mudstone and sandstone of the Elliot Formation. Two dolerite dykes bisect the catchment, both of them running roughly in a north-south direction (De Decker, 1981). Vegetation is dominated by *Themeda triandra* and *Tristachya leucothrix* grasses and can thus be classified as sour grass veld.

Rainfall measurements during eight years of research average at 1083 mm per annum (Van Huyssteen et al., 2005). Reference evaporation is 1400 mm per annum. The average summer temperatures range between 10 and 25 °C, while the

average winter temperatures range between 4 and 18 ^{o}C. Severe frost occurs in winter, while snow can occur on the higher altitudes (Roberts *et al.,* 1996).

Soils in the catchment are characterized by varying degrees of hydromorphy (Roberts *et al.,* 1996) and include soils of the Hutton form (freely drained); Tukulu, Bloemdal, Pinedene and Avalon forms (well drained) and Kroonstad and Katspruit forms (very poorly drained gley soils). A large part of the catchment is dominated by a marsh covered by soils of the Kroonstad and Katspruit forms.

The cooperation of Prof. S. Lorentz is greatly valued. His experience is clearly reflected in the careful way in which the Weatherley project has been planned and executed since 1995. All the hydrograph data and much of the soil water content data come from his records (BEEH, 2003).

Data for three plinthic soils (Longlands form) namely profiles P201, P204 and P225, a typical poorly drained soil (Katspruit form), P218, and a typical freely drained soil (Tukulu form), P212, were used to calculate daily water contents and calculate averages for six years. The soils were described in detail (Turner, 1991) and classified (Soil Classification Working Group, 1991). Soil water contents were measured weekly since 1 January 1997 at 300 mm depth intervals with a CPN neutron water meter and with tensiometers.

The CPN neutron water meter measurement points do not always have a precise fit with the diagnostic soil horizon. Reference to diagnostic soil horizons implies the measurement point best representing that horizon. The detail is presented in a report to the Water Research Commission by Van Huyssteen et al. (2005).

3 Results and discussion

Many hydrological processes is active in the landscape, some of which is active in the soils (Figure 2). The Longlands soil form has an orthic A horizon overlying an E horizon overlying a soft plinthic B horizon (Soil Classification Working Group, 1991). The soils are mature displaying three clearly visible horizons (Figure 3). Profiles P201 and P204 are of the family with yellow E horizons when measured moist. Profile P225 is of the family with grey E horizons. "Yellow" families of soils of the Longlands and Kroonstad forms had shorter periods of $AD_{s>0.7}$ relative to the soil families with grey coloured E horizons (Van Huyssteen et al., 2005). The plinthic character of the soft plinthic B horizon is poorly developed in P201 but well developed in P204 and properly matured in P225. P201 has developed on solid rock (Elliot sandstone) visible in the bottom of the profile pit. P204 and P225 developed on a clay layer of Eliot and Molteno material respectively. P201 is situated in a topslope position about 200 m from the crest (Figure 2). P204 is just above the shelf and P225 close to a small stream on the lower terrace. The underlying rock and clay probably restricts vertical drainage resulting in lateral drainage being an important process in this soil as indicated in Figure 2.

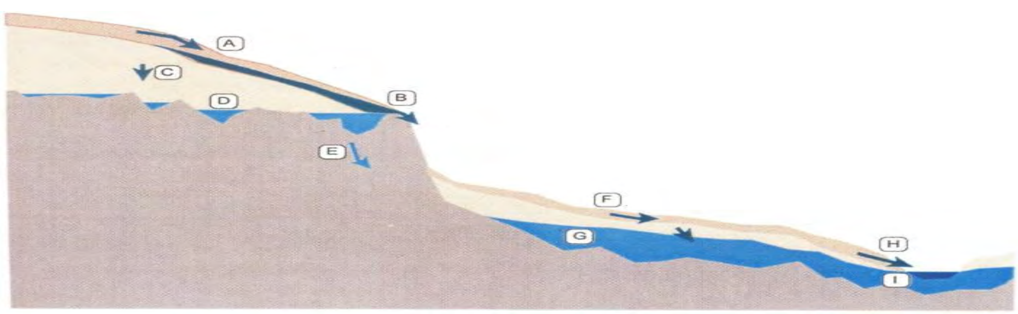

Figure 2 Distribution of the three soils of the Longlands form in the landscape. P201 is close to the top of the slope. P204 at point B and P225 at point F. P212 (Tukulu) is under the shelf in the talus slope and P218 (Katspruit) in the marsh The arrows and symbols indicate conceptual water flow and storage mechanisms in the Weatherley catchment (Lorentz, 2001)

In an attempt to describe the drainage characteristics of the soils the yearly patterns in changes in water content were visually analysed for repetitive features. Typical curves for the upper three measurements in P201 and P225 and the upper two measurements of P204 occurred in 1998, 1999 and 2001. This pattern may be typical of plinthic soils in Weatherley as it also occurred in other plinthic soils namely P234 (Avalon) and P237 (Westleigh). In this paper the focus will be on the soils of the Longlands form. The data for six years supply detail information of the behaviour of the soils under specific conditions but the question arises as how the soils behave in general.

Long-term daily mean soil water contents of the soils showed four phases in the soil water regime of the Longlands soils. A wet phase occurred in the peak rainy season, followed by a draining phase, a drying phase and a wetting phase (Figure 4). The wet phase resembles a period when the main factors in the soil water balance are addition of water by rain and loss of water by drainage – lateral and vertical. The draining phase occurs in the period when rainfall is on the decrease and drainage therefore plays a more dominant role. This phase is not very clear as periodic rain in autumn and high ET interferes. However it shows well in the data of the year 2001 when rain stopped abruptly in autumn. In spite of the low winter temperatures and little vegetative activity the role of evapotranspiration (ET) are probably the main factor in the drying

phase. The water contents changes very little during this phase. The drying phase is stopped by the rainy season and a wetting phase starts. The wetting phase continues until the water holding capacity of the profile is reached and a fluctuating water table forms.

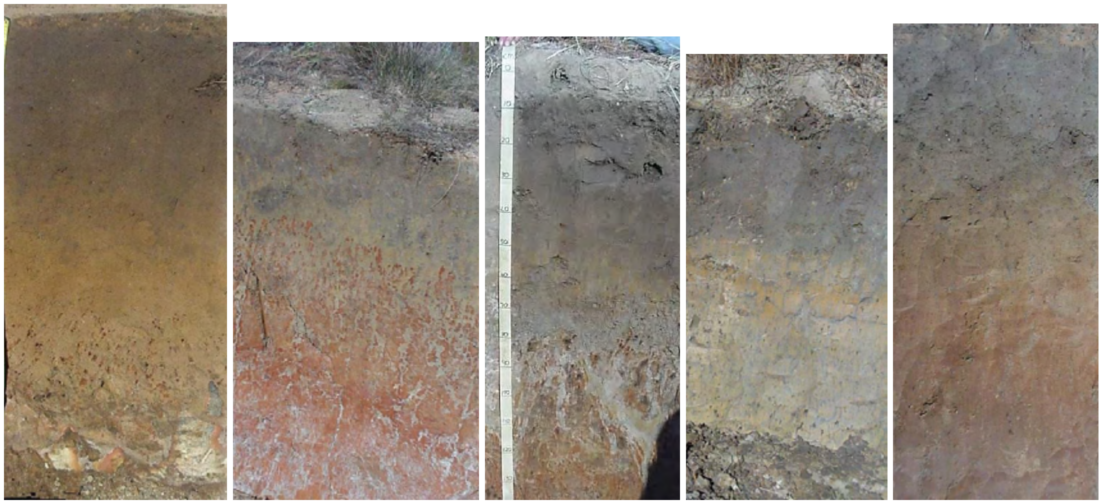

Figure 3 Profile morphology of soils P201, P204, P225 (all Longlands), P218 (Katspruit) and. P212 (Tukulu)

The soil of the Katspruit form has two phases only namely a wetting and drying phase. It seems to get wetter for most of the duration of the rainy season. After the rainy season the soil loses water systematically until it starts to rain again. The freely drained Tukulu P212 is perceived to have no draining phase as it is expected to drain effectively during the rainy season. The wet phase may represent a condition of the drained upper limit under freely draining conditions.

The amplitude of the soil water regime cycle are best developed for plinthic soils varying from 0.32 (P201 and P204) to 0.28 (P225) degrees of saturation over the year cycle (Figure 4). For the Katspruit and Tukulu it is 0.24 and 0.20 respectively. This tendency fits the interpretation of the soil water regime of plinthic soils.

A draining phase is expected in the soil water regime of soils with water tables and it is expected to coincide with the time of interflow recorded by the hydrograph (Figure 1). The steeper slope of the of the soil water regime curve immediately after the wet cycle i.e. a change of about 0.1 degree of saturation per month, are defined as the draining phase. It is uncertain what the contribution of ET or vertical drainage is. Although it is poorly defined with current data it probably occurs mainly in April and May. From the $AD_{s>0.7}$ values in Table 1 it can be deduced that because the subsoils of the soils of the Longlands form generally all starts saturation with the beginning of the wet phase in January, P201 is expected to drain in the wet phase only, P204 for another month and P225 for another four months after the wet cycle. The soil of the Katspruit form however, can drain continuously during the year. During the draining phase the soil water balance is probably controlled be the phreatic water table and ET. The steep decline in water content in April and May probably indicate a faster section of the draining phase. At middle October however, the degree of saturation starts to climb. This coincides with the start of the rain.

The drying phase is by far the longest phase as it stretches over five and seven months to the beginning of November in the soils of the Longlands and Tukulu forms respectively with ET as the main factor extracting water. It takes two months for the soils to get filled with water to the extend that the subsoil saturate and rain and drainage balances. The wetting phase of the soils of the Longlands and Tukulu forms stretches from November to December and for the soil of the Katspruit from middle October to end of March.

4 Conclusions

Although the soil water regimes of all 28 soils monitored in the Weatherley catchment differed, three very similar soils of the Longlads form, occurring on quite different landscape positions, also have similar patterns of soil water regimes.

The results indicate that freely drained soils probably only make a contribution to the hydrology of the catchment by feeding the lower vadose zone during the wet phase. The soils of the Longlands form may extend the contribution to the draining phase and the duration of that contribution probably relates to the degree of plinthite development. Soils of the Katspruit form probably makes the most important contribution to the hydrograph during peak flow and very little during the draining phase.

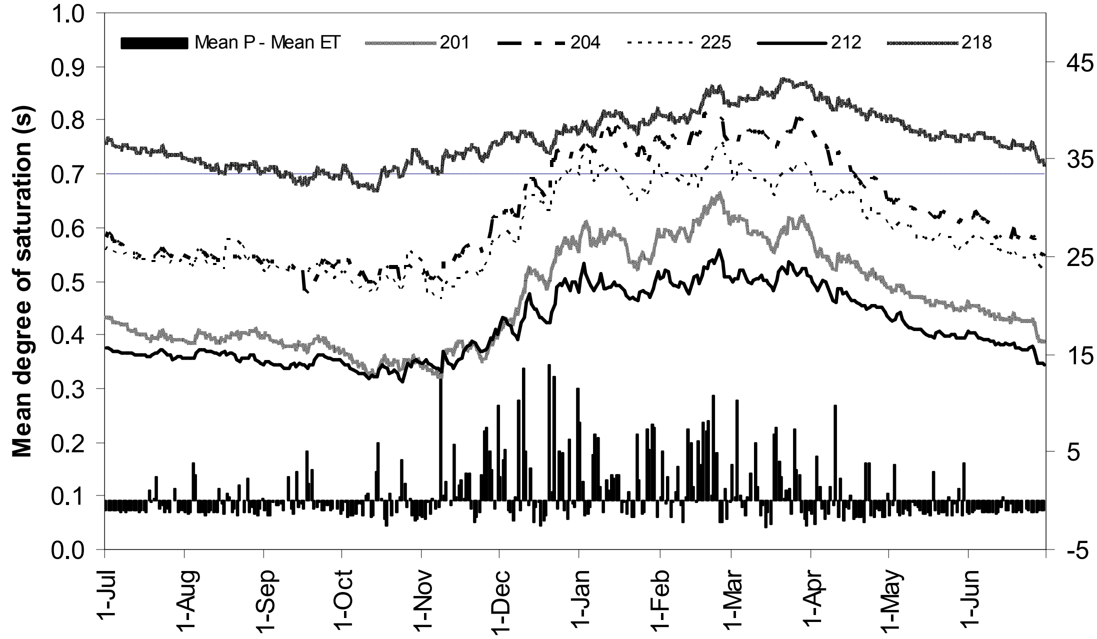

Figure 4 Long-term average annual soil water changes. Water content is expressed as a fraction of the pore volume. The bars is mean rain – mean ET.

5 Acknowledgements

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